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Fri-Mo-Po.06-01: JT-60SA Central solenoid conductor hotspot risk analysis for high voltage protection

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The upgrade to JT-60SA tokamak (R=3m, a=1.2m) was conducted within a Europe-Japan collaboration agreement featuring the implementation of superconducting magnets. In 2021, an arcing issue on EF1 coil led to an overall insulation reinforcement against high voltage on the magnet system. Because the Central Solenoid (CS) is less accessible for repair it deserves specific attention related to its voltage exposure. Risk mitigation was initiated by decreasing the power supply voltage during plasma scenario current transients, but in order to further minimize risk, it was decided to also address the case of fast discharge events, less frequent but likely to be the risk-driver case as it induces the highest voltage on the magnet. The voltage value during discharge being proportional to the external dump resistance, it is envisaged to decrease this resistance of 30%. The consequence is a slower current decrease after a quench event, inducing a higher Joule energy absorbed by the conductor and therefore a higher temperature rise in the conductor, increasing the risk of thermo-mechanical degradation due to hotspot occurrence.
It is therefore needed to conduct a risk analysis associated to this mitigation action and the present paper exposes the different steps passed in this aim. The first step includes the development and cross-check of two thermo-hydraulic models of CS winding pack that independently evaluate the maximum temperature of CS conductor components using THEA and GANDALF tools. Then, several standard reference cases of quench events and associated CS discharges are investigated for different quench detection conditions. The overall results are presented and discussed regarding the influence of detection settings. Further to the reference cases in question, several parametric studies are conducted considering variants on parameters bearing uncertainties in their definition. This encompasses e.g. the quench location, the quench zone length, the current variation pattern or the copper RRR value. This step aims to establish a more accurate estimation of the impact derived from those intrinsic uncertainties on quench event features. In addition some potential investigations on the use of possible margins are shown.
For this risk evaluation studies, a particular emphasis is given to the methodology followed for definition of hotspot risk criteria, and the rationale and references having contributed to the establishment of those methodologic elements. After application of those rules to the above mentioned modelling results, the evaluation outcomes are discussed with the aim of issuing a consolidated assessment on the absolute risk faced by the CS magnet in case of quench event. Finally, recommendations are made regarding the possibility to validate and implement the decision to decrease the CS magnet dump resistance by the JT-60SA project team in order to better protect the CS from applying high voltage.

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